A Training Manual for Training of Trainers on Postharvest Handling of Some Horticultural Crops

Volume 12

By

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Postharvest Handling of Some Horticultural Crops

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Introduction

Fruit and vegetables form an essential part of a balanced diet. They are an important part of world agricultural food production, even though their production volumes are small compared with grains fruits and vegetables are important sources of digestible carbohydrates, minerals, and vitamins, particularly vitamins A and C. In addition, they provide roughage (indigestible carbohydrates), which is needed for normal healthy digestion. Despite their importance more than 50% of the total production is wasted in developing countries due to different reasons. To meet the increasing demand, it is important to reduce losses, where proper post harvest management plays an important role for preserving quality and minimize loss and wastages.

Quality is an increasingly important factor in the production and marketing of biological products. In the ISO 9000 standard (developed by the International Standards Organization), quality is defined as “the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs. If something is not a quality product, this implies that the product does not meet a certain standard that has been adopted by the consumer. In this case, the market price is adversely affected. Conversely, if a product is perceived to be a quality product, then it sells for a better price.

Sources of postharvest losses

Physical damage occurs from harvest to consumption. Bruises, cuts, abrasions, and fractures occur as a result of poor handling or inadequate packaging. Damage dramatically increases water loss and susceptibility to infection by postharvest fungi and bacteria. In addition, respiration and ethylene production are enhanced in wounded tissue. Postharvest technologists attempt to maintain quality, slow deterioration, improve shelf life ensuring consumers to have high quality produce to purchase. They seek to control the handling, transport, and storage conditions to ensure optimal quality. Postharvest physiologists seek to understand and develop strategies to control the basic physiological and biochemical changes that occur in harvested plant products during handling and storage. It is only through such an understanding, that sensible and meaningful recommendations can be made for manipulation of elements in the post harvest handling to ensure quality products reach all markets. A thorough understanding of the events starting from the harvesting through the consecutive operations is required to reap the benefits of the system.

Harvesting

Maturity is described as Physiological and Commercial maturity**.** Physiological maturity**,** refers to that stage of development when maximum growth has occurred and proper completion of subsequent ripening can occur even if the product has been harvested. *Commercial maturity* is that stage of development of a fruit or vegetable that is required by the market. It may have little relation to physiological maturity and may occur at various stages of ripeness depending on individual consumer preference. Final eating quality is critically dependent on harvesting at the correct maturity stage, so that normal ripening can occur with the concomitant development of flavor, texture, aroma and juiciness required by consumers. In many fruits, ripening occurs either on or off the tree. Optimum eating quality for many vegetable crops is attained before full maturity. Examples include peas, green beans, broccoli, sweet corn, zucchini and leafy vegetables; if these products are left attached to the parent plant and not harvested at the correct time, their quality is much reduced.

Harvesting removes the product from its source of minerals and water (from roots) and in most cases from its source of energy. Freshly harvested horticultural products remain alive, very active metabolically, as reflected in their relatively high respiration rate. The developmental processes of maturation and ripeness merge and overlap. Deterioration commences at harvest; postharvest technologies are designed to slow the rate of ripening and hence quality decline. If deterioration is rapid, poor-quality product can be removed at the point of production or packing at which quality inspection occurs; if deterioration is slow the product may pass initial quality inspection yet be of reduced acceptability to consumers because of poor appearance, texture, or taste. This is likely to make future purchases unlikely.

Great care must be taken during harvesting of perishable fruits and vegetables to avoid physical damage. Any mechanical damage that occurs at harvest, during movement of product to the pack house, or through grading and packing lines will result in enhanced respiration, elevated ethylene production, water loss and increased susceptibility to infection by postharvest pathogens, all of which can induce rapid deterioration and loss of quality.

A number of simple but effective steps can be taken to reduce physical damage from occurring during this phase of the harvesting and handling system. These include:

- careful handling of the product at all stages of the operation
- good sanitation and hygiene with all equipment (this may include addition of chlorine [as hypochlorite at 50–150 ppm] to water dumps in the packing and grading line to reduce microorganisms)
- maintenance of packing equipment to prevent excessive drops onto hard surfaces

and padding of all machinery surfaces on which products may impact.

Curing is a simple method of reducing losses due to decay and water loss during storage of some products including some citrus fruit, root, tuber, and bulb crops.

Crops such as tomato are collected into larger containers, which are transported out of the field. The transfer into the field bin is a serious potential cause of damage, unless pickers are well trained. Fruit-on-fruit impact and impacts against the sides and base of the bin are potential sources of severe bruising. The transport to the collecting shade also is potentially damaging to the produce. In most cases, the fruit as yet have no packaging to protect them, and they must be transported over rough farm tracks and other roads to the grading shed or market, which may be several kilometers away. Training and good management of drivers is essential to keep transport speeds to levels that are safe for the product.

Reception

It is vital to have documentation about a crop arriving at a grading shed. The documentation should record details of who the product is from, the harvest date, and the delivery date to the shed, as well as full details about the crop and pesticides used during its growth. This allows the grower to receive appropriate credit for the product and ensures that quality guidelines have been adhered to prior to arrival of the product at the shed. Spray certificates and other documentation also may be required. Reliable documentation requires careful inventory control, including clear procedures for recording all shipments and marking the field bins.

Vegetables are generally less sensitive to handling damage, and so rougher handling seems to be acceptable at this point in the chain. However, moisture loss and product deterioration may result, particularly if vegetables are not displayed under appropriate temperature and high-humidity conditions. Much retail shelving includes overhead misting to maintain product freshness. For optimum product quality the volume of product on display should be determined to match the demand, so that products only spend a short time on display before they are purchased. Customers should have a limited selection to reduce the amount of "picking over." Shelves then need to be replenished at regular intervals, with fresh product placed beside or under rather than on top of the older product on display. The remainder of the stock should be stored in appropriate cool stores at the rear of the shop.

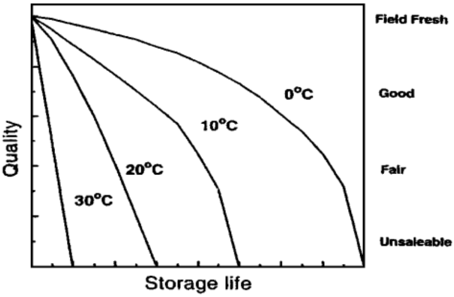
Respiration

All living things respire to generate energy for continued metabolism.
Respiration is highly temperature dependent. The lower the temperature (down to 0±C) of harvested fruit and vegetables the lower the respiration rate.
Consequences of lowering respiration rate include

- Reduction in carbohydrate loss
- Decreased rate of deterioration
- Increased storage and shelf life

Low-temperature storage is the major weapon that the postharvest operator has to maintain quality and extend life of harvested products
Low temperatures not only reduce respiration rate, but also reduce

- Water loss through transpiration
- Nutritional loss Postharvest decay
- Ethylene production

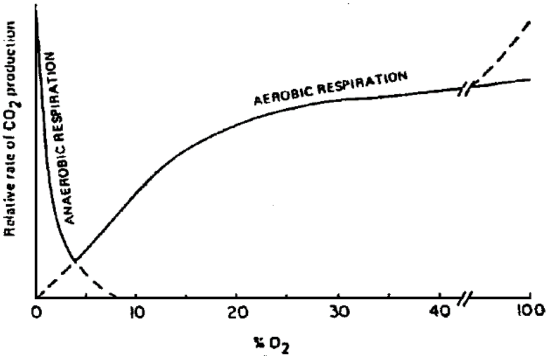


Source: ASAE. 1999. Agro processing Engineering. CIGR Handbook of Agricultural Engineering Vol IV.

Practical application of such information has been incorporated into successful cool chain management for many products. Immediately after harvest, products should be placed in a well-ventilated shade environment to prevent large temperature increases that occur if products are exposed to direct sunlight. Rapid cooling as soon as possible after harvest (to reduce respiration rate) is used commonly in the horticultural industry, particularly for very perishable products such as strawberries and broccoli but also for kiwifruit and apples. Hydro cooling, vacuum cooling, or forced air-cooling is used widely to remove field heat rapidly. The method chosen depends on the crop.

Respiration rate of horticultural products varies, but as a general rule perishability is a function of respiration rate; the greater the respiration rate the more perishable the product and the shorter the time it can be stored and still maintain acceptable quality.

It has long been recognized (since the 1920s and 1930s) that controlling the atmosphere around products influences respiration rate. Respiration rate is a function of O_2 and CO_2 concentration. Respiration decreases as O_2 concentration in the environment, and hence inside the product, is reduced. Eventually an O_2 concentration is reached, below which CO_2 production rapidly increases as anaerobic respiration predominates. The O_2 concentration at which respiration is at a minimum is called the *anaerobic compensation point* (ACP). The ACP or lower oxygen limit varies with temperature, fruit type, and cultivar and among fruit, probably because of varying skin permeance to O_2 and CO_2 movement. [Derivation of ACP needs to be undertaken for Development of atmospheres withO_2 lower than theACP inevitably leads to off flavors and loss of quality. Knowledge of ACPs for crops allows optimization of controlled-atmosphere conditions for different products and avoids problems such as development of off flavor and physiological damage that may result from anaerobic respiration and subsequent fermentation processes at suboptimal O_2 atmospheres



A schematic representation of the effects of O2 Concentration of aerobic and anaerobic respiration rates of
fresh vegetables.

Generally controlled-atmosphere stores operate with 0±C atmosphere containing 1% to 5% CO_2 and 1% to 3% O_2, depending on crop and cultivar. Recent improvements of gas and temperature control systems have allowed cool-store operators to refine these ranges; for some cultivars of apple, 0% CO_2 and 1.0% O_2 are being used. The lower the O_2 concentration, and the higher the CO_2 concentration, the higher the risk of problems arising, generally manifested as some form of external or internal product browning.

Ethylene Production

- Ethylene is a ubiquitous, naturally occurring gaseous compound produced by plants. It is particularly important in the maturation, ripening and senescence of fruits, flowers and vegetables. At very low concentrations can influence many aspects of plant growth and development like coordination of several ripening events, induction of abscission and color change from green to yellow, Induction of softening, juice development, and flavor and promotion of uniform ripening. This is mainly manifested in climacteric fruits. Climacteric fruit are those that produce relatively large amounts of ethylene during ripening on or off the tree. Peak production generally coincides with a concurrent respiratory peak within 3 to 10 days of harvest, after which respiration may decline

- Ethylene in non-climacteric fruits induces unwanted accelerated senescence even at low temperatures, induced loss of green color in leaves. Induction of abscission in flowers and fruit, Increased organ softening, Induction of some physiological disorders and initiation of ripening in climacteric fruit that cannot be reversed. Non-climacteric fruits do not produce either a respiratory peak or an ethylene surge during ripening, they show a steady decline in respiration rate and a low rate of ethylene production as ripening proceeds and are ready to eat at harvest. Exposure to ethylene, or an analogue of ethylene, stimulates ethylene production, but only as long as the source is present

- Ethylene-sensitive products should not be stored with climacteric fruit. Ethylene-absorbing material can be placed inside sachets (e.g., potassium permanganate on perlite). Stringent attention to hygiene conditions in and around packing sheds and ensuring that exhaust fumes do not contaminate products

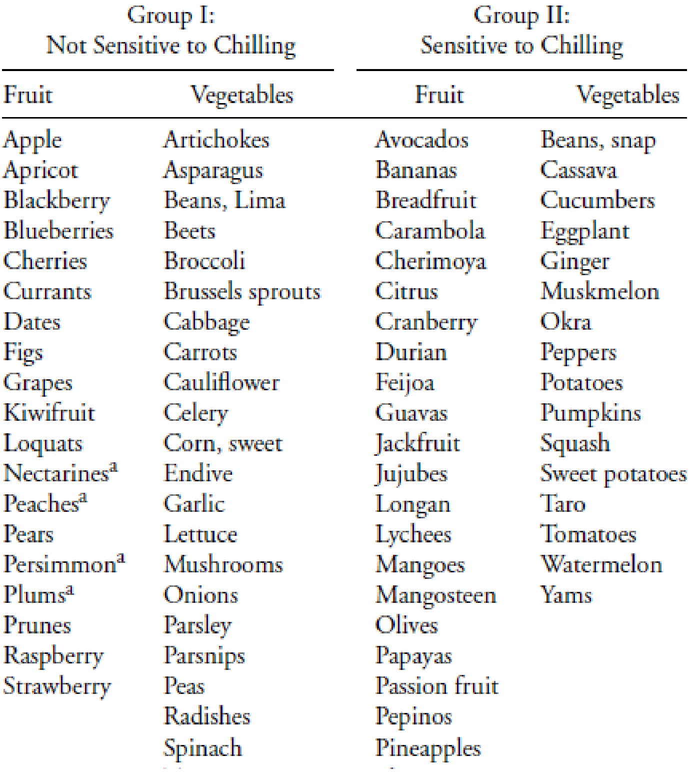
respiratory behavior during ripening

Climacteric	Nonclimacteric
Apple	Blackberry
Apricot	Cacao
Avocado	Carambola
Banana	Cashew apple
Biriba	Cherry
Blueberry	Cucumber
Breadfruit	Date
Cherimoya	Eggplant
Durian	Grape
Feijoa	Grapefruit
Fig	Jujube
Guava	Lemon
Jackfruit	Lime
Kiwifruit	Longan
Mango	Loquat
Muskmelon	Lychee
Nectarine	Okra
Papaya	Olive
Passion fruit	Orange
Peach	Peas
Pear	Pepper
Persimmon	Pineapple
Plantain	Pomegranate
Plum	Prickly pear
Quince	Raspberry
Rambutan	Strawberry

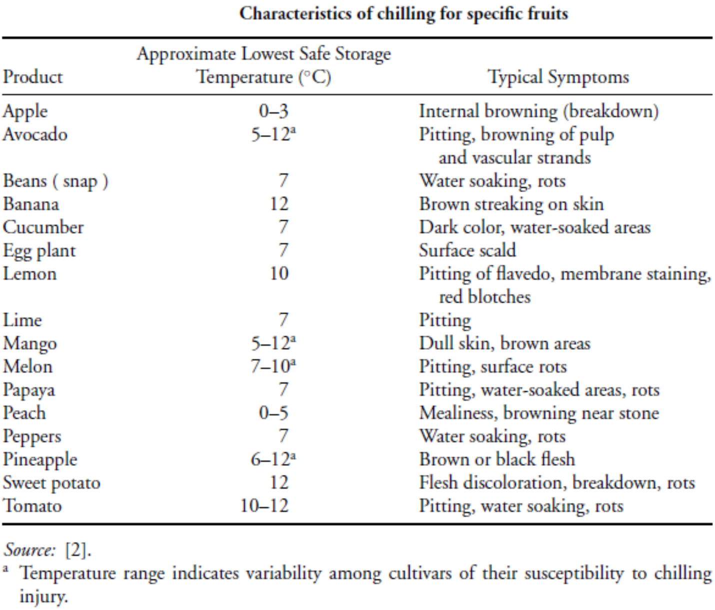
Chilling Injury

Most tropical and subtropical products are susceptible to chilling injury when exposed to temperatures above freezing but below a critical threshold temperature for each particular product. These chilling temperatures cause breakdown of cellular membranes, resulting in loss of compartmentalization within the cells of the tissue, increased leakiness, water soaking of tissue, and eventually pitting or browning. Some chilled fruit fail to ripen normally, while in others there is an accelerated rate of senescence and a shortened shelf life. Symptoms of chilling injury are varied and depend on the product but include surface pitting, surface browning, internal browning to vascular tissue or in parenchyma cells, water soaking, wooliness of texture. The ultimate symptom of severely chilled products is decay; the original cause of such rotten produce may not be realized unless the temperature history of the product is known. Chilling injury is avoided by storing susceptible products above their threshold damage temperatures, although reduction of injury can be achieved by exposing products to preconditioning or intermittent temperatures or to high temperatures (38–45±C) prior to low-temperature storage.

Fruit and vegetables classified according to sensitivity to chilling injuries



Group I: Not Sensitive to Chilling		Group II: Sensitive to Chilling	
Fruit	Vegetables	Fruit	Vegetables
Apple	Artichokes	Avocados	Beans, snap
Apricot	Asparagus	Bananas	Cassava
Blackberry	Beans, Lima	Breadfruit	Cucumbers
Blueberries	Beets	Carambola	Eggplant
Cherries	Broccoli	Cherimoya	Ginger
Currants	Brussels sprouts	Citrus	Muskmelon
Dates	Cabbage	Cranberry	Okra
Figs	Carrots	Durian	Peppers
Grapes	Cauliflower	Feijoa	Potatoes
Kiwifruit	Celery	Guavas	Pumpkins
Loquats	Corn, sweet	Jackfruit	Squash
Nectarines[a]	Endive	Jujubes	Sweet potatoes
Peaches[a]	Garlic	Longan	Taro
Pears	Lettuce	Lychees	Tomatoes
Persimmon[a]	Mushrooms	Mangoes	Watermelon
Plums[a]	Onions	Mangosteen	Yams
Prunes	Parsley	Olives	
Raspberry	Parsnips	Papayas	
Strawberry	Peas	Passion fruit	
	Radishes	Pepinos	
	Spinach	Pineapples	



Characteristics of chilling for specific fruits

Product	Approximate Lowest Safe Storage Temperature (°C)	Typical Symptoms
Apple	0–3	Internal browning (breakdown)
Avocado	5–12[a]	Pitting, browning of pulp and vascular strands
Beans (snap)	7	Water soaking, rots
Banana	12	Brown streaking on skin
Cucumber	7	Dark color, water-soaked areas
Egg plant	7	Surface scald
Lemon	10	Pitting of flavedo, membrane staining, red blotches
Lime	7	Pitting
Mango	5–12[a]	Dull skin, brown areas
Melon	7–10[a]	Pitting, surface rots
Papaya	7	Pitting, water-soaked areas, rots
Peach	0–5	Mealiness, browning near stone
Peppers	7	Water soaking, rots
Pineapple	6–12[a]	Brown or black flesh
Sweet potato	12	Flesh discoloration, breakdown, rots
Tomato	10–12	Pitting, water soaking, rots

Source: [2].

[a] Temperature range indicates variability among cultivars of their susceptibility to chilling injury.

Storage

Marketing of perishable commodities often requires storage to balance day to day fluctuations between product harvest and sales; for a few products, long-term storage is used to extend marketing beyond the end of harvest season. Long-term storage is feasible only if the product gains enough value during the storage period to pay for the cost of storage. To minimize product quality loss the storage must slow biological activity of product by maintaining the lowest temperature that will not cause freezing or chilling injury and by controlling atmospheric composition; slow growth and spread of microorganisms by maintaining low temperatures and minimizing surface moisture on the product; reduce product moisture loss and the resulting wilting and shrivel by reducing the difference between product and air temperatures and maintaining high humidity in the storage room; and reduce product susceptibility to damage from ethylene gas.

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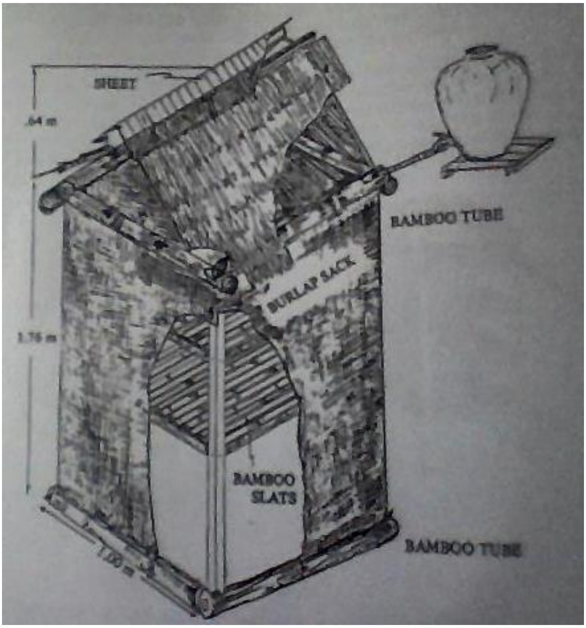
Evaporative Cooling

Evaporation of water requires heat. Evaporative-cooling systems extract this heat from the product. Evaporative-cooling techniques are very energy-efficient and economical.

A well-designed evaporative cooler produces air with a relative humidity greater than 90%. Its main limitation is that it cools air only to the wet-bulb temperature of the outside air. During the harvest season in the United States, wet-bulb temperatures vary from 10 to 25±C depending on location, time of day, and weather conditions. This temperature range is acceptable for some chilling-sensitive commodities. The water for cooling in the systems mentioned previously comes from domestic sources. It is also practical to cool by evaporating water from the commodity. Snap beans have been cooled in transit by erecting an air scoop above the cab of the truck that forces outside air through a bulk load of beans. This system prevents heat build-up and keeps the beans at or below the outside air temperature. Using this system for any great length of time may result in excessive water loss. In small farms packing houses can be made from natural materials that can be moistened with water. Wetting the walls and roof first thing in the morning creates conditions for evaporative cooling of the packinghouse that is made from straw. A packhouse could be made with walls of wire mesh that hold charcoal. By moistening the charcoal with water each morning, the structure will be evaporately cooled during the day.

A simple evaporative cooler can be constructed from simple materials such as burlap and bamboo. The drip cooler shown here operates solely through the process of evaporation, without the use of a fan. Cooling will be enhanced if the unit is kept shaded and used in a well-ventilated area.



Source Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition)

Night Cooling

In some parts of the world, significant differences between night and day temperatures allow nighttime ventilation to be a means of refrigeration. In dry Mediterranean or desert climates the difference between daily maximum and minimum temperatures can be as great as 22±C during the summer. Night cooling is commonly used for unrefrigerated storage of potatoes, onions, sweet potatoes, hard-rind squashes, and pumpkins. As a rule, night ventilation effectively maintains a given product temperature if the outside air temperature is below the desired product temperature for 5 to 7 hours per day.

Low nighttime temperatures can be used to reduce field heat simply by harvesting produce during early-morning hours. It is theoretically possible to produce air temperatures below nighttime minimums by radiating heat to a clear sky. A clear night sky is very cold, and a good radiating surface such as a black metal roof can cool air below ambient temperature.

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Well Water

In some areas, well water can be an effective source of refrigeration. The temperature of the ground more than about 2 m below the surface is equal to the average annual air temperature. Well water is often very near this temperature.

High-Altitude Cooling

High altitude also can be a source of cold. As a rule of thumb, air temperatures decrease by 10±C with every kilometer (5±F per 1000 ft) increase in altitude. It is not possible to bring this air down to ground level because it naturally heats by compression as it drops in altitude. However, in some cases it may be possible to store commodities at high altitudes in mountainous areas. For example, in California most perishable commodities are grown in the valley floors near sea level. However, much of the production is shipped east across the Sierra Nevada over passes about 1800 m high. Air temperature has the potential of being 18±C cooler, and it may reduce energy costs to store perishables there rather than on the valley floor.

Underground Storage

Caves, cellars, abandoned mines, and other underground spaces have been used for centuries for storage of fruits and vegetables. As mentioned previously, underground temperature is near the average annual air temperature. Underground spaces work well for storing already cooled produce but not for removing field heat. The soil has a poor ability to transfer heat. Once the refrigeration effect is depleted from an area, it does not regenerate rapidly. This can be overcome by installing a network of buried pipes around the storage. Cooled air is pumped from the pipes to the storage area, allowing the harvest of cooling capacity from a greater soil volume.

The Storage Building

The storage must be sized to handle peak amounts of product. The floor area can be calculated knowing the volume of the produce and dividing by the maximum product storage height and adding area for aisles, room for forklift maneuvering, and staging areas. Maximum storage height can be increased by use of shelves or racks and forklifts with suitable masts. Multistory structures generally are not used because of the difficulty and expense of moving the product between levels. The building ideally should have a floor perimeter in the shape of a square. A rectangular configuration has more wall area per unit of floor area, resulting in higher construction cost and higher heat loss compared with a square configuration. Entrances, exits, and storage areas should be arranged so that the product generally moves in one direction through the facility, especially if the storage facility is used in conjunction with a cooler to remove field heat.

Onions

Onion are major crops in the tropics, which accounts for nearly 30% of total global production Estimated loss of total crop in these countries is high and can reach 20% to 95% [5]. Losses between wholesale and retail of over 9% have been reported for Spring onions [6]. Although some tropical countries are net importers, export potential of onions is developing in several tropical regions partly because if dried and packed properly the bulbs can be transported for considerable distances without deteriorating. Storage for several months also is possible if suitable bulb temperatures can be maintained. Proper storage environment is critical to minimize bulb softening, shriveling, weight loss, and development of storage rots and decay. Different cultivars have variable storage life. In general, poor-keeping cultivars are less pungent and have a low dry-matter content, a low refractive index, and high relative rate of water loss and total water loss, especially in the period immediately following harvest. Poor-storing cultivars also are more susceptible to storage rots, sprout more readily [11], and benefit more from “curing.”

Physiology and Quality

The commercially grown bulb onion is a biennial crop with origin in Asia. The bulbs are naturally dormant organs adapted to maintaining the plant as viable during a period unfavorable for growth. In the native habitat of the wild ancestors of onions and garlic the bulbs may have enabled the plants to survive periods of summer drought and winter cold [1]. The onion shows a distinctly marked dormancy between the vegetative and the generative growth periods. Therefore, bulbs are natural storage organs, well adapted for long-term crop storage.

The outer dry skins are very important for maintaining the dormancy, preventing water loss, and excluding pathogens. Bulb storage rests on knowledge of the physiology plus a knowledge of the pathology of diseases of stored bulbs. Depending on variety, the dormancy and storage period ranges from a few days to several months. The storage life depends also on climatic conditions (especially temperature) during storage. The dormancy is shortened by external stimulation such as mechanical stress during harvest and handling, lighting during storage, and fluctuation of storage temperature and humidity. During dormancy the bulb is protected by the outer scales. In this way the outer scales lose water and form dry skins while the inner scales stay fresh and firm. As dormancy declines the sprout leaves elongate and become visible. Sprout development takes energy from all scales and causes the bulbs to become soft, resulting in quality loss.

Temperature Effects

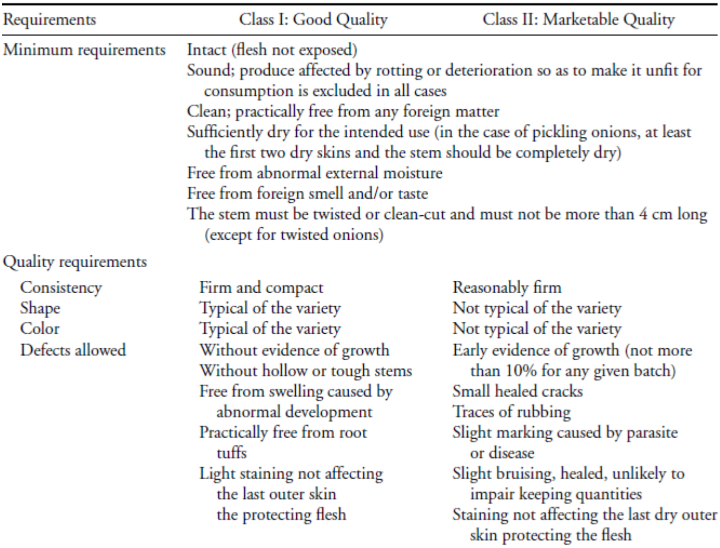
Sprouting is depressed during dormancy at lower and higher temperatures. The rate of elongation of sprouts within the bulb and the rate of leaf initiation were much faster at 15 than at 0 or 30±C. Therefore, sprout development in onion bulbs, unlike most physiological processes, does not increase in rate progressively as temperature increases. Once sprouting has occurred in rooted bulbs, sprout growth rate increases progressively with temperature.

The rate of postharvest deterioration (spoilage) of produce generally is proportional to the rate of respiration. Bulb onions have a low respiration rate (3–4 mg CO_2¢kg¡1¢h¡1 at 5±C), and this increases with corresponding increases in temperature. Green onions have higher respiration rates, comparable to leafy vegetables, at the same temperature. A low oxygen level in the storage chamber halves the rate of respiration. In storage, as time progresses, the rate of respiration increases. If bulbs are wounded, their rate of respiration increases and reaches a maximum after about 12 hours. The higher level is measurable over the whole storage period. If the dry outer skins of onions are removed, the respiration rate of bulbs increases nearly two-fold and the rate of water loss also increase. Bulbs with the skin removed also sprout more rapidly than those with intact skins.

Maturity

The condition of onion leaves is a good indicator of the maturity and general state of the bulb. Bulb onions that are to be stored should be allowed to mature fully before harvest, this occurs when the leaves bend just above the top of the bulb and fall over]. Storage losses at this maturity normally are lower than those harvested before the tops collapse. Harvesting should begin when 50% to 80% of the tops have gone over, before it is possible to see split skins exposing white flesh. As a practical guide, one should conduct sample counts on the number of bulbs that have fallen over in a field. When the percentage of bulbs that have fallen over reaches about 70% to 80% of total, then one should harvest the entire crop. Bulb yields up to 5 ton¢ha¡1 have been reported. Harvested crop should be allowed to dry or cure and ripen in the sun for several days after lifting.

Example of on international OECD quality standard: Summary of the requirements



Requirements	Class I: Good Quality	Class II: Marketable Quality
Minimum requirements	Intact (flesh not exposed) Sound; produce affected by rotting or deterioration so as to make it unfit for consumption is excluded in all cases Clean; practically free from any foreign matter Sufficiently dry for the intended use (in the case of pickling onions, at least the first two dry skins and the stem should be completely dry) Free from abnormal external moisture Free from foreign smell and/or taste The stem must be twisted or clean-cut and must not be more than 4 cm long (except for twisted onions)	
Quality requirements		
Consistency	Firm and compact	Reasonably firm
Shape	Typical of the variety	Not typical of the variety
Color	Typical of the variety	Not typical of the variety
Defects allowed	Without evidence of growth Without hollow or tough stems Free from swelling caused by abnormal development Practically free from root tuffs Light staining not affecting the last outer skin the protecting flesh	Early evidence of growth (not more than 10% for any given batch) Small healed cracks Traces of rubbing Slight marking caused by parasite or disease Slight bruising, healed, unlikely to impair keeping quantities Staining not affecting the last dry outer skin protecting the flesh

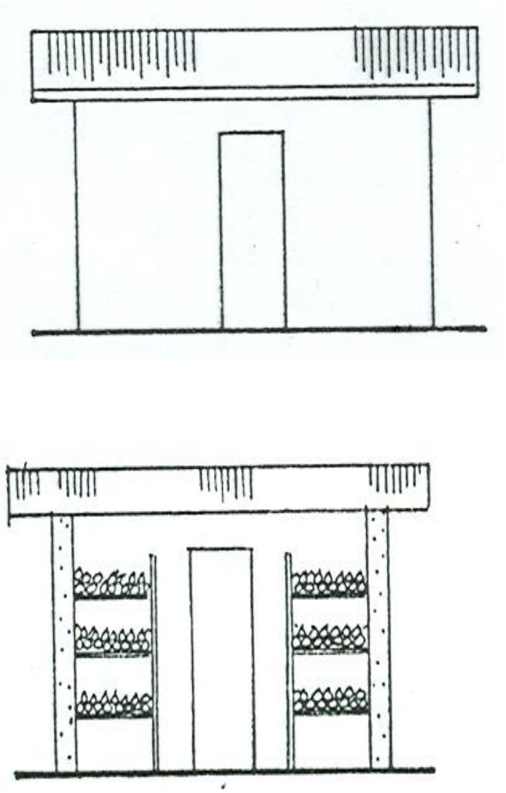
Harvesting

Hand harvesting usually is carried out by levering the bulbs with a fork to loosen them and pulling the tops by hand. This is the common practice in many developing countries in which farming is manual labor–intensive. In developed countries, especially on large scale farms, mechanical harvesting commonly is used. The harvesting techniques depend upon the at harvest time. In areas where warm, dry weather occurs reliably, the curing and bagging of the crop can be done in the field (two-phase harvesting). In wetter, temperate regions, mechanical harvesting and artificial heating and ventilation for drying are essential to produce reliably high-quality bulbs on a large scale.

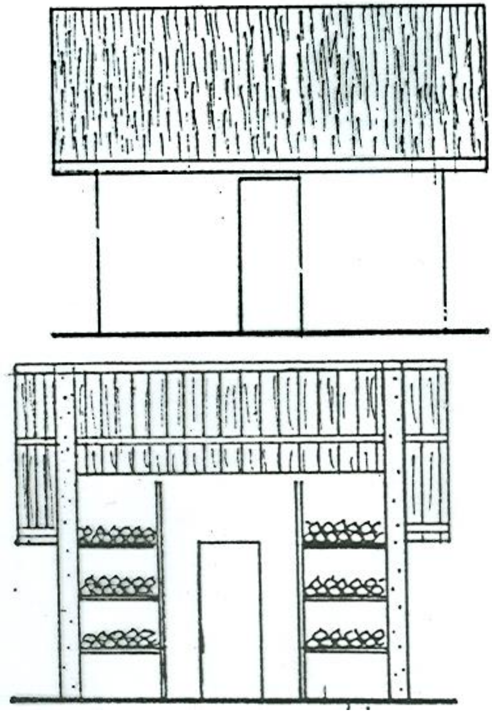
The Ethiopian Experience

Bulb onion is an important crop in. Ethiopia. It is a cash source for farmers and also many people make their living by trading the crop. A comprehensive statistic for such losses is not available for Ethiopia.; However, it has been estimated that in onion producing areas like the Upper Awash Agricultural Development Enterprise, which used to store bulbs in sacks of 25kg each on prepared shelves, 40% to 70% of the stored bulbs were lost during storage periods of 30 to 45days respectively (Ketema, pers. com). Most farmers do not have proper storage facilities and they directly bring onion to the market immediately after harvest. Fearing losses, farmers usually unload their entire stock within a month after harvest. As a result, during this period prices rule very low due to glut situation. Thereafter, the rise in prices is quite rapid and sometimes-wide fluctuations occur leading to dissatisfaction amongst the producers as well as consumers.

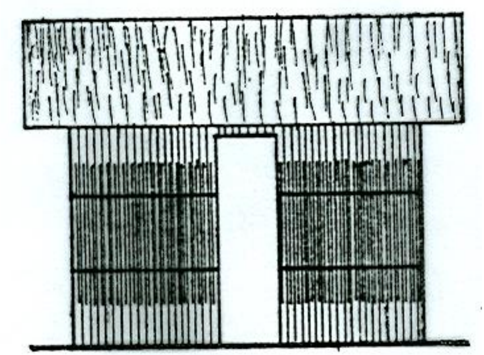
To combat the problem a study on storage structures was conducted at Melkassa Agricultural Research center. Three naturally ventilated storage structures, with different roof and wall design and of approximately 6 quintals capacities were constructed from locally available materials (Fig.1). The wall of structures (St-I and St- II) were made of 20 cm thick mud bricks, while that of St-III (control) was a slated wall structure covered with sorghum stock erected side by side. The roof of St-I was constructed using corrugated iron sheet under laid with 5 to 7cm thick straw as a ceiling. On the other hand, thatched grass was used as roofing for St- II and St-III. About 500kg bulb was stored in each store. The performance of the structures was measured for two dry (January –May, 2001) and wet (July –October, 2001) seasons over a storage period of 4 months in each case.

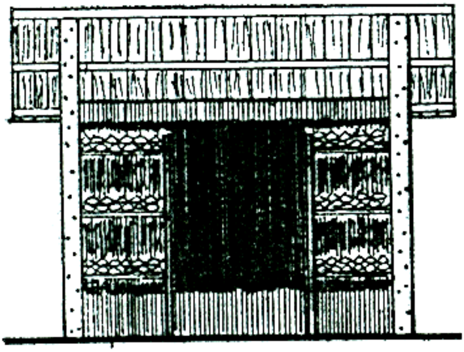


Structure I



Structure II





Structure III (control)
Figure 1 Naturally ventilated onion storage structures.

The three structures were evaluated on their relative advantages on controlling humidity, weight loses bulb sprouting, incidence of rotting and length of safe storage period. The results indicated that

- Structure I and II achieved daily minimum temperature increment of 5°C to 6°C during dry season and 3.8°C to 6.4 °C during the wet season which appeared to be outside the critical range for sprout induction.

- For each season, bulbs stored in the main treatment store sprouted less than those stored in the control structures and the incidence of sprouting was higher during wet season than the dry season
- Structure I increased the shelf life of bulb onions up to two months with an overall loss of 17.9% and 22.36% during the dry and wet seasons respectively. In the same order total losses in structure II was 20.17% and 27.64 %.

Based on these results the two structures were recommended for popularization.

Tomato

Tomato is one of the important vegetable crops grown by most farmers especially in the Central Rift Valley of Ethiopia. The problem to date has been getting good seeds at a reasonable price to the farmer

Vegetable seeds in this country are made available through imports from countries like the Netherlands and South Africa, incur high transport and other overhead costs like storage and handling, which makes the seed expensive when it gets to the end user. Tomato seed costs between 600 and 650 birr/kg. As the storage condition is poor and very likely to stay on shelf for a long time before being sold, by the time it gets to the farmer, the viability of the seed decreases and farmers are penalized in lower rate of seed germination and emergence. Areas around the Melkassa Research Center and in the Rift Valley are suitable for growing horticultural crops like tomato. If seed with high vigor and low cost could be made available to the farmer, the crop could be grown cheaply and made available at a reasonable price to the consumer. To make this a reality, effort was made to avail a low-cost seed extracting equipment to seed producers.

Generally, tomato extraction is done either purely as tomato seed extraction or as an additional product during the processing of tomatoes for puree or juice. In the process, the harvested tomato is put in the crusher, the crusher squashes or crushes the fruit and the resulting mixture of the gelatinous seed, juice and fruit residue is passed through a screen to separate off the gelatinous from the bulk of the remaining material**.** The crushed material is passed in to a revolving cylindrical screen which allows the seed and juice to pass through the mesh, while the fruit debris pass the cylindrical screen to drop in the field. The debris is collected later on, while the fruit and juice are collected in separate container. The separated mixture is left to ferment at 21^{0}C for 96 hours, which is possible under the Melkassa condition. The seed extracted as such is washed in a series of sieves smaller than the mean weight diameter of the tomato seed in a gradient of 1:50. They are dried on trays (George 1985).

A study was launched at the Melkassa Agricultural Research Center with the objective of making seed available through the development of low-cost seed extracting equipment. At the start of the design process**, t**he required power and revolution needed to affect the extraction was determined using the model extractor and a provision was made to retain the pulp, which was a byproduct of the process. The fabrication was made using mild steel at the beginning. Thirty-millimeter rectangular hollow section (RHS) was used for the base frame. The concave part was made from 1mm sheet metal with drilled holes of 10mm diameter at 20mm distance. The separator had triangular blades welded to a 30mm diameter shaft on to which is welded a conveying and cutting unit arranged in an auger fashion. The equipment had a provision for pressured water, to help wet pulping, a seed collecting unit and a water trough, a side line pulp pulverizer and mashed pulp collecting unit. The driving unit had a handle and a sprocket chain assembly to vary speed and torque. The equipment was tested using tomato secured from the Horticulture Department. The equipment was placed near a water source. A water hose was attached to the water inlet pipe of the equipment. The tomato was fed in to the pulping unit after the operator had started rotating the pulping unit and the water system turned on and directed into the chamber. About 30kgs of tomato was fed, the test time, throughput, weight of the pulp, weight of seed extracted were recorded during the testing. The weight of the pulp, which remained after the operation, was also determined. After the operation, the machine was thoroughly cleaned. The extracted seed was dried and germination rate was also determined.

Figure 3. The final tomato extractor

Table 1. Comparative test on seed extraction using the mechanical and the traditional (manual) extraction method

Test no.	Throughput (kgs.)	Extraction time (secs.)	
		manual	extractor
1	3	39.4	9.5
2	3	38.23	8.45
3	3	40.49	8.63

Table 4. Seed extracted using a higher throughput using the improved final prototype compared to the trampling practice using two people**.**

No	sample	Time (min)		Extracted seed (gms)	
		Manual**	Machine	Manual	Machine
	30kg	6	4.95	177.9	140.3
	30kg	6.5	5.06	170	133.9

**Two operators trampling by foot

Table 5. Comparison of seed extraction using the improved version against the conventional practice using one person

Sample	Time (min)	
	Manual	Machine
12kg	20	2.3
12kg	20	2.02
12 kg	20	1.96
Mean	20	2.09

The results showed that the machine was ten folds faster in the operation. Currently the manual practice at Melkassa has changed to trampling. The machine in this case too, is much faster than the traditional practice. Besides, the pulp which remains after trampling cannot put into any use because of the unhygienic condition of pulping. With the new machine the pulp is not only conserved, but is pulverized and converted to juice which can be some source of income for the farmer as well. A lower seed recovery rate is observed in the machine compared to the traditional practice, which is attributed to some problems of fabrication observed due to the escaping of some tomato materials through some non-tight-fitting parts, which needs serious attention during fabrication.

The new equipment was found satisfactory in terms of seed recovery and pulverization of the non-seed material for other uses. The equipment is basically manually operated, which makes it versatile to work anywhere in the country. There is minimal loss; the equipment also pulverizes the pulp and other non-seed debris, it has the potential to kick start a cottage industry in tomato producing areas.

Evaporative cooler

The work on the evaporative cooler has been going on for some time. Preliminary studies on water holding capacity and degree of difference in temperature between the ambient and the one inside the walling material has been studied using single strap and double strap filla material and on scoria. Encouraging results were recorded in all cases.

Four different types of cooling structures using charcoal, scoria, RHB and filla are constructed. The size of each structure is 200cmX 150cm inside with the overall dimension of 228X178. The height of the structure is 2.2 meter on the longer side and 1.8 meter on the shortest side. Each is filled with the walling material up to a height of 20 cms below the roof. The poles have a minimum of 10 cm diameter with perlins nailed both on the inside and outside. Each except the RHB is covered with a net wire to keep the filled walling material in place. Each will be completely saturated with water before the produce is introduced into the store and will be regularly wetted by fitting the structure with a water tank and perforated plastic hose running around the top of the structure. The selected site is shaded from sunlight most of the day and is along a corridor with wind speed ranging upto 3km/min Testing is carried out by watering the three stores with 100 litres of water each starting at 9:30 for 20 minutes each. The ambient temperature and R.H and that of inside the store are recorded every two hours under no load condition. Differences in the temperature are recorded between the stores and that of the outside environment and among the stores are observed. The test will continue with load here after.

Table 1. Watering for 30 minutes unlike the usual 20 minutes

Test No	Date	Time	Inside the Cooler		Outside	
			Temp	Humidity (%)	Temp	Humidity (%)
	Charcoal					
	Aug 3/2016	10;10	18	75	19.5	72
		11:10	19.5	74	21	70
		12:10	20	73	22.5	68.5
		1;10	21.5	72	22.5	69
		2;10	21	71	22.5	67
		3;10	21	70	21	68
		4;10	21	71	22	67
	Scoria					
	Aug 3 /2016	9:50	17	77	19	72.5
		10;30	19	75	21	70.5
		11;50	19	74	22	69
		12;50	20.5	73.5	22	68
		1;50	20.5	72	23	67
		2;50	20	71	21.5	67.5
		3;50	19.5	72	22	67.5
	filla					
	Aug 3/2016	10:30	19	73	20.5	71
		11;30	20.5	72.5	21.5	60.5
		12;30	21	71.5	23	69.5
		1;30	22	70.5	22	67.5
		2;30	22	69.5	22	66
		3;30	21.5	69	22	67
		4:34	21	70	23	67
	Block					
	Aug 3/2016	10:20	18	74	20	71.5
		11:20	19.5	72	21	70
		12;20	20.5	71	22.5	68
		1:20	21	70	21.5	68
		2:20	20	70	22	66.5
	:	3:20	21	70	21	68
		4:20	21	70	23	67
	Charcoal					
	Aug 4/2016	10;10	19	75	23.5	69
		11:10	20	73	25.5	65
		12:10	20.5	72	26.5	64
		1;10	23	70.5	26	64
		2;10	23	67	27	63
		3;10	22.5	68	27.5	60.5
		4;10	22.5	68	27	61.5

Test No	Date	Time	Inside the Cooler		Outside	
			Temp	Humidity (%)	Temp	Humidity (%)
	Scoria					
	Aug 4 /2016	9:50	18	77.5	23	70
		10;50	19	75	25	66
		11;50	20	73	26.5	64
		12;50	21.5	69.5	26.5	63
		1;50	22	68	26.5	64
		2;50	22	70	27	61
		3;50	23	68	26	62
	filla					
	Aug 4 /2016	10;30	19.5	74	24	67.5
		11;30	21	72	26	64.5
		12;30	22	69	26	64
		1;30	22	66	26	63
		2;30	23.5	66.5	26.5	61
		3;30	24	65	27.5	60
		4:30	24.5	65	26.5	61.5
	Block					
	Aug 4/2016	10:20	20.5	72	24	68
		11:20	21	71	26	64.5
		12;20	22	70	27	63.5
		1:20	22.5	67	26	63.5
		2:20	24	66	27	62
	:	3:20	23	65.5	27.5	60
		4:20	24	67	27	62

Papaya

Papaya is an important fruit crop in Ethiopia especially in the rift valley. People living in Melkassa, Alem Tena, Meke, Zewaye grow lots of papaya and is sold to travelers on the Mojo Awasa road and are found in abundance at the grocery stores in Nazareth, Melkassa, Mojo, Meke, Zewaye and Shashemene. Though papaya is economically important, proper harvesting technique is not used. The fruit is usually harvested by shaking the tree, which detaches and eventually drops the fruit and wounds it as the skin is tender. At the Melkassa Agricultural Research Center, Horticulture farm, they use two people per tree during harvesting. One person detaches the fruit using a long pole, while the second person strives to catch the fruit. At times the person may miss and the fruit falls down on the ground, which results in bruising and total damage of the fruit. Due to such problems the harvested papaya should be sold immediately to avoid further losses. In general, this mode of harvesting shortens the shelf life of the crop and farmers pay in harvesting loss due to rotting.

An improved papaya harvester, which totally eliminated the problems encountered in the traditional system was developed at Melkassa Agricultural Mechnaization Research Center.

The unit has two gathering jaws constructed from 2mm sheet metal with 10 mm diameter holes drilled throughout the body of the unit to make it as light as possible. A spongy padding was added on its surface to avoid bruising of the papaya during gathering. This gathering unit is welded to a 30mm RHS of 100 mm length, which in turn is attached to the access pole using bolts. A rope tied to a ring welded on one jaw and passing through another ring welded to the second jaw and tied to a latch to the lower end of the access pole was used to easily open the two jaws of the unit during gathering and to hold them together at other times. The access pole is three meters long, fabricated from a 2mm thick 20 mm diameter pipe. The access pole is attached to the gathering unit shank by bolts. A ring is welded at 2/3 of the length down, through which passes a rope for the manipulation of the gathering unit. With this length access pole, one can easily reach a good fruiting tree, which will not be more than four meters in most of the cases.

Tests on time taken to detach the fruit, degree of bruising, from different heights of a tree were conducted at different times in the horticulture department.

Time taken for harvesting individual papaya fruits from different heights.

No.	Weight (kg)	Major axis(mm)	Minor axis(mm)	Time (sec)
1	1	185	110	2.91
2	1	153	69	3.72
3	0.8	155	64	5.12
4	1.2	194	92	2.84
5	1.2	166	91	316
6	1	189	91	3.16
7	1.1	158	90	3.56
8	0.7	196	110	4.38
Mean	1	174.5	96.75	3.6

The papaya harvester has also a provision for harvesting fruits like mango, which need to be detached from tall trees reaching 5 meters, by changing the fruit gripping unit with a mango clipping unit. This harvesting aid has a capacity of collecting of about 2kgs of mango in a minute. This could vary depending on the height, canopy and branch configuration of the mango tree. As the fruit is detached it is collected in the basket placed right below the cutting knife, where the fruit lands smoothly without any injury.

Mango harvesting using the papaya harvester with a mango clipping unit June

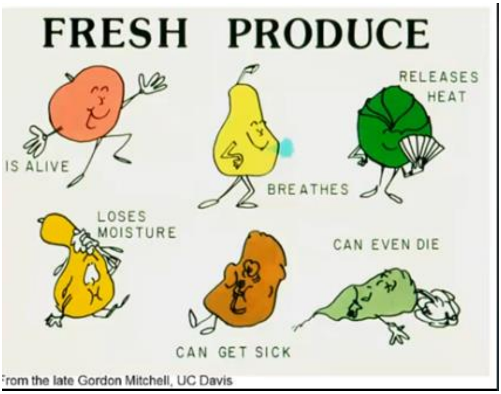
No.	Time (min)	Weight	Number of mangoes collected
	1	1	3
	4	3.5	7
	2	5.5	9
	2	2.5	5
	5	3	8
	1	1.6	4

Figure 1. Picking papaya using improved picker

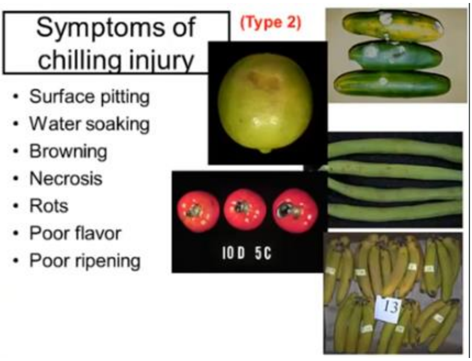
Figure 2. Papaya picked using the improved tool

Fig 3. Picking papaya the traditional way

Fig 4. Papaya picked the traditional way



rom the late Gordon Mitchell, UC Davis



Symptoms of chilling injury

- Surface pitting
- Water soaking
- Browning
- Necrosis
- Rots
- Poor flavor
- Poor ripening